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Shoreland Development Density and Impervious Surfaces

How do they affect water resources?

How much is too much for our lakes and streams?

Introduction

When a landowner develops a waterfront lot, many changes may take place including the addition of driveways, houses, decks, garages, sheds, piers, rafts and other structures, wells, septic systems, lawns, sandy beaches and more. Many of these changes result in the compaction of soil and the removal of trees and native plants, as well as the addition of impervious (hard) surfaces, all of which alter the path that precipitation takes to the water.

Each of these alterations decreases the ability of the shoreland area to serve its natural functions: removal of trees and native plants eliminates the food and shelter on which wildlife depends, natural beauty is replaced with manmade materials, water cannot soak into the ground thereby increasing stormwater runoff that carries fertilizers, pesticides and other pollutants to the lakes and streams. If 50% of a lot is converted to impervious surfaces, half of this lot is no longer capable of filtering rainwater or providing the food and shelter on which wildlife depends.

Changing one waterfront lot in this fashion may not result in a measurable change in the quality of the lake or stream. The cumulative effects, however, can be enormous. These changes are framed by issues such as stewardship of the resource, the rights of the public, and land owners' rights – both of those developing land and those whose land is being affected by this development.ⁱ

Shoreland development has increased dramatically.

The influence that such changes have on water quality might appear relatively insignificant when it occurs on one lot on a large lake, but an examination of recent trends suggests that shoreline development is increasing both in numbers and intensity. From 1960 to 1995, the number of dwellings along 235 northern Wisconsin lakes increased an average of 216 percent.ⁱⁱ At the same time, people are building bigger homes but lot sizes are not increased proportionally. If present development rates persist, all undeveloped lakes not in public ownership could be developed by 2020.ⁱⁱⁱ

Shoreland impacts are cumulative.

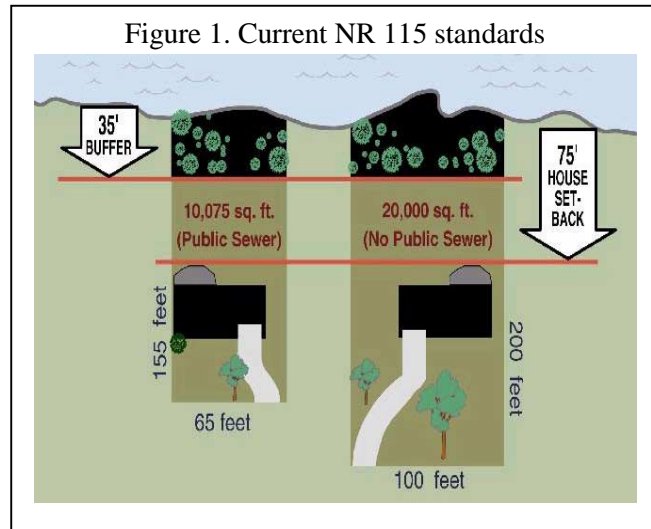
In the past, we could stress our aquatic systems without seeing a noticeable change in the quality of the water resource. But “cumulative” effects, such as the same stress applied later in time to an already stressed system can have a much larger impact. This is like a boxer who can take a punch in round 1 and still be standing, but when hit with the same punch in round 15 is knocked out. The cumulative effect of all the previous punches reduces the resiliency of the boxer. In one Wisconsin study, a 10% reduction in the area covered with lakes and wetlands resulted in about 10% greater flood flows and erosion when the watershed started out with 40% lake and wetland area. When the same 10% reduction was applied to a watershed that started out with only 10% of its area containing lake and wetlands, flood flows and erosion increased by 250 to 500%.^{iv} Thus, a system's response to stress depends on what condition the system is in to begin with. These effects are cumulative, and how systems responded to the stresses of our ancestors may not give us a good indication of how they will respond as we and our descendants stress them.^v

Will the cumulative impact of many homeowners making such changes to their shorelands degrade water quality, eliminate, fragment or degrade habitat for fish and wildlife, and increase erosion and the potential for flooding? Likewise, could the cumulative impact of many buildings close together, near the water with minimal screening degrade the natural scenic beauty of the shoreline? To explore these questions, a review of the hydrology, water quality, fish and wildlife habitat and shoreline aesthetic studies relevant to shoreland development are summarized here.

State shoreland management standards

In the mid 1960's when the current minimum standards for county shoreland zoning ordinances were first adopted in Chapter NR 115, there was clear recognition that development density (lot size requirements) had a significant effect on the shoreland management objectives.

Specifically, Chapter NR 115 requires lots served by public sanitary sewers to have a minimum average width of 65 feet and a minimum area of 10,000 square feet. Lots with a septic system must have a minimum average width of 100 feet and a minimum area of 20,000 square feet. The current rule does not include a minimum statewide standard for impervious surfaces to address the increased runoff and pollutant transport. This is not surprising because at the time this rule was adopted regulations focused on controlling point sources of pollution. Since the mid-1990s many Wisconsin counties have significantly revised their shoreland ordinances, choosing larger lot sizes and impervious surface caps.



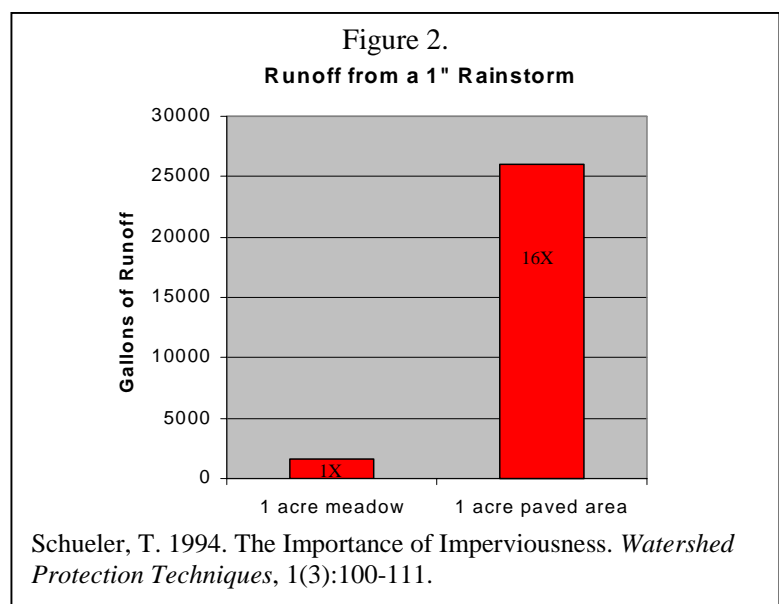
Limiting the density and intensity of shoreland development can safeguard our lakes and streams. Specifically the statute authorizing shoreland zoning [s. 281.31(1), Wis. Stats.] requires that:

“... (t)he purposes of the regulations shall be to further the maintenance of safe and healthful conditions; prevent and control water pollution; protect spawning grounds, fish and aquatic life; control building sites, placement of structure and land uses and reserve shore cover and natural beauty.”

The remainder of this document will look in more detail at how development density and impervious surfaces affect the hydrology, water quality, wildlife habitat and the natural beauty of Wisconsin's shorelands.

Hydrology: Where do rain and snow go?

The simple answer is “it runs downhill.” How much water is involved? On average in Wisconsin, we receive approximately 30-34 inches of



precipitation a year.^{vi} Of this amount, 18 to 25 inches evaporate or are transpired, and the remaining 7-13 inches either run off to surface waters or infiltrate into the ground.^{vii} During a one-inch storm 27,152 gallons of water fall on one acre of land, enough to fill three and one-half rooms that are 10'x10'x10'.

An important question for the health of lakes and streams is how much of the precipitation flows over the land surface directly to lakes and streams and how much filters into the ground and is either stored as groundwater or slowly makes its way back into rivers. An unintended result of development is that impervious surfaces cause more water to run off the landscape and less to infiltrate to groundwater. For instance, a parking lot produces 16 times more runoff (on B soils: those with moderate infiltration rates of 0.15-0.30 in/hr when thoroughly wetted) than a meadow of the same size for the same storm event.^{viii}

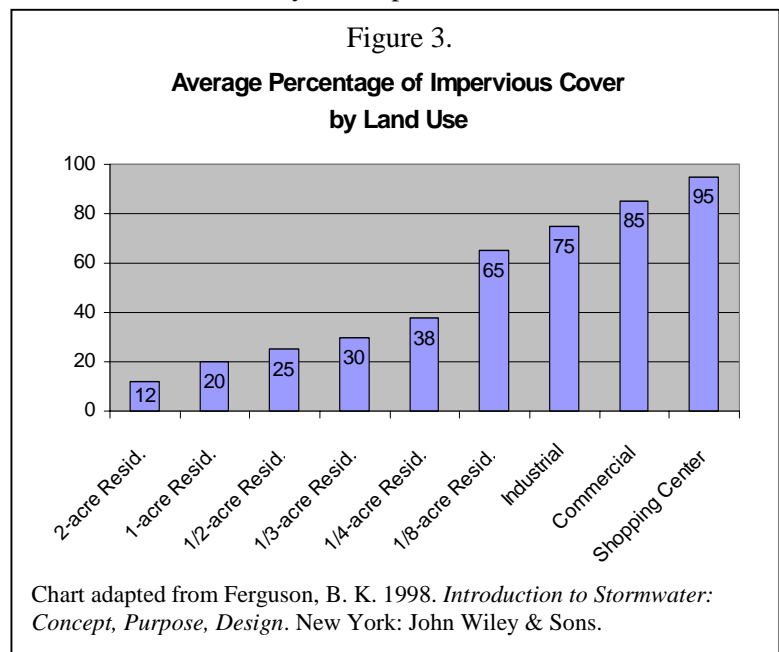
Figure 3 shows the average percentage of imperviousness for different land uses and lot sizes. Typically the percentage of impervious cover is higher for smaller lots. Additionally, industrial, commercial and retail uses have much higher percentages of impervious cover than residential development.

Natural shoreland functions are lost when impervious surfaces are added.

Table 1 provides a comparison of the amount of runoff from two forks of the Pheasant Branch watershed near Madison. After the South Fork was converted to commercially developed land with 31% connected impervious surface, the amount of runoff was 690% that of the North Fork that is agricultural land with little impervious surface. In this situation, the runoff increased by over seven inches a year while groundwater recharge decreased by nearly three inches per year.^{ix} As a result of the high erosion rates, the City of Middleton has spent over \$2.3 million in the last 25 years in an attempt to protect bridges and sewer lines from erosion.^x

Table 1. Average annual water budget for two portions of the Pheasant Branch watershed (budget not balanced because of change in groundwater storage)^{xi}

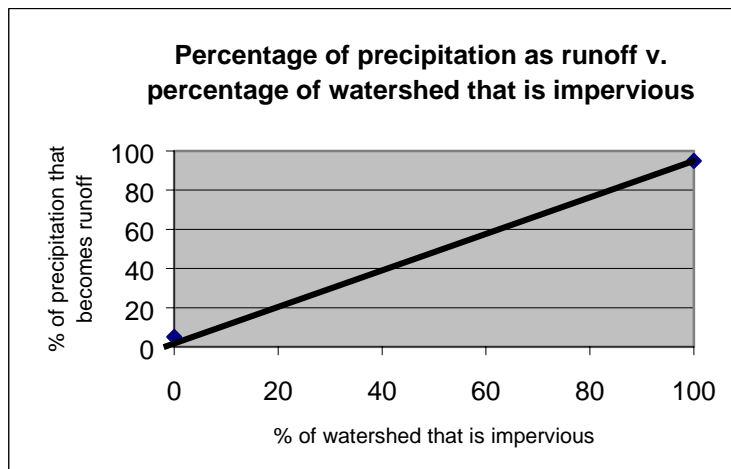
	North Fork Agricultural land with little impervious surface	South Fork Commercially developed land with 31% connected impervious surface
Precipitation	35.0 inches	35.0
Runoff (overland flow)	1.2	8.3
Groundwater recharge	8.8	6.0
Evapotranspiration	24.6	20.5



The effects of different land cover types on nutrient delivery is discussed further under the phosphorus section.

Figure 4 illustrates research findings that runoff increases as the percentage of the watershed that is impervious increases. This runoff data was derived from 44 small catchment areas across the country for EPA's Nationwide Urban Runoff Program.^{xii}

Figure 4.



Schueler, T. 1987. *Controlling Urban Runoff: A practical Manual for Planning and Designing Urban Best Management Practices*. Metropolitan Washington Council of Governments. Washington, D.C.

The quantity and quality of water that infiltrates or runs off also depends on season, topography, plant cover, land use and soil type.

Intense rainstorms produce more runoff than slow, steady rains. Steep slopes have more runoff than flatter lands. Urban areas have more runoff than forests, fields and pasturelands. Rock and clay soils have more runoff than organic soils or sands.^{xiii} As shown in Table 2, groundwater provides a large portion of the water in the Waupaca River that drains an area of thick sandy deposits. This is in contrast to the Big Eau Pleine River near Stratford that drains an area with thin clay over relatively impermeable rock and receives a significant portion of its flow from runoff.^{xiv}

Table 2. Comparison of stream flow from different types of drainage areas

River	Waupaca River	Big Eau Pleine
Drainage area characteristics	Sandy deposits	Thin clay over relatively impermeable rock
Flow during dry periods from groundwater*	0.5-1.0	0 – 0.2
Annual flow* = groundwater + runoff	0.78	0.75

*cubic ft per second per square mile of drainage area

Holt, 1965. *Geology and Water Resources of Portage County, Wisconsin*, U.S.G.S. Water-Supply Paper 1796, p. 17

When runoff increases, this water bypasses the natural water filter provided by soil, microbial action and vegetation and carries additional sediment, nutrients and other materials in its path directly to surface waters. This increased transport of materials from land to water can be a substantial source of nutrient and sediment loading.

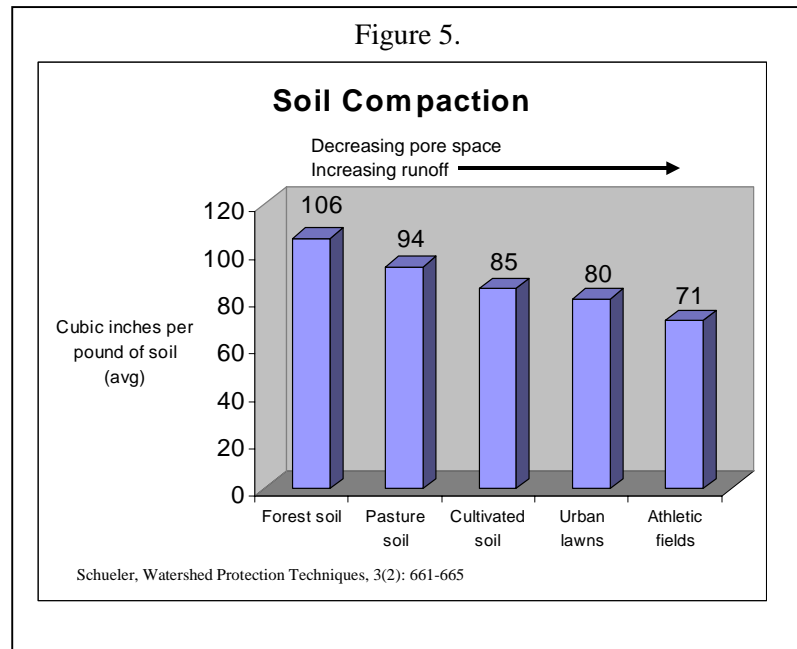
Do the effects depend on where the impervious surfaces are located?

Yes! Not surprisingly impervious surfaces closer to the water have a greater impact because there is less opportunity for the runoff from these areas to soak into the ground or be filtered before reaching the lake or stream. The findings from a study of 47 watersheds in southeastern Wisconsin indicated that 1 acre of

impervious surface within 100 meters (~330 feet) of the stream had a negative effect on fish populations and diversity equivalent to 10 acres of impervious surface more than 100 meters from the stream.^{xv}

Lawns have limited natural shoreland functions.

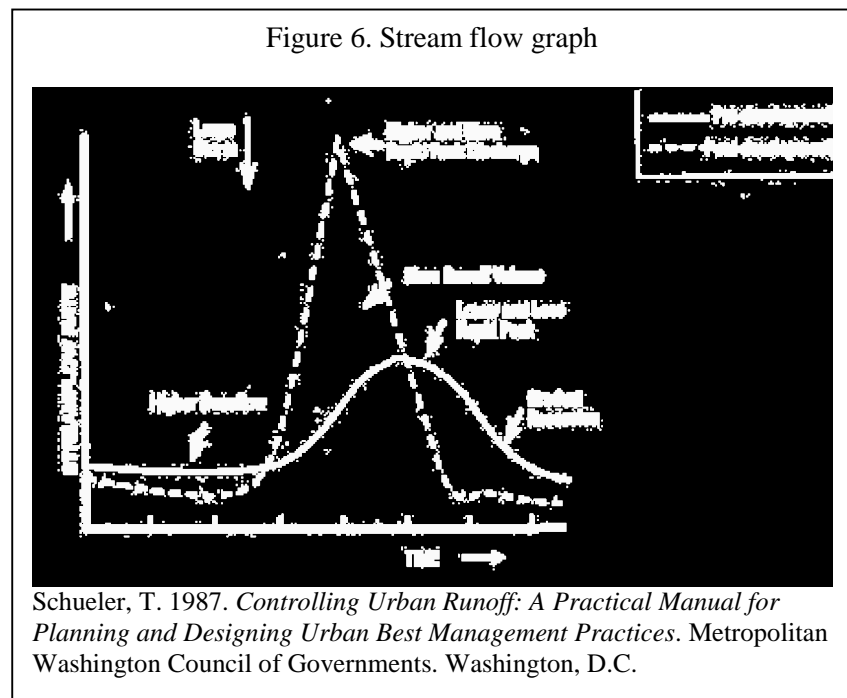
Lawns often comprise the largest fraction of land area within low-density residential development and often have similarities with impervious surfaces. Although lawns are pervious, they have sharply different properties than the forests and farmlands they replace in terms of compacted soils, greater runoff and much higher input of fertilizers and pesticides.^{xvi} Figure 5 shows that a pound of soil in a lawn has 24% less volume than forest soil and 15% less volume than pasture soils. The decreased volume of the lawn soil reflects decreased pore space and ability to infiltrate water, resulting in increasing runoff. Cultivated soils and those in lawns are more similar due to disturbance and compaction.



Blades of turf grass are flat and easily flattened during a runoff event whereas native grasses and forbs typically have round, square or triangular stems that stay upright to slow runoff velocity and filter it during a storm. The effects of lawns on water quality and wildlife habitat are discussed below.

Impervious surfaces change the flow, size and shape of streams.

With increased areas of impervious surface and compacted soil, a greater fraction of annual rainfall is converted to surface runoff. Under these conditions, streams become 'flashy', meaning runoff occurs more quickly, peak flows become larger, and critical dry season flows decrease because less groundwater recharge is available,^{xvii} as shown in Figure 6.

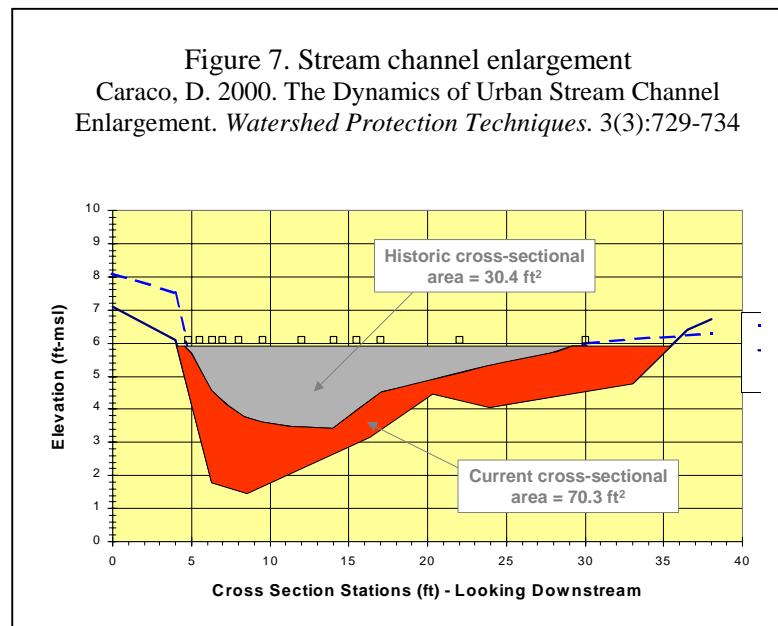


Increased runoff and stream flashiness result in physical changes to the stream including:

- wider and/or deeper stream channels,^{xviii} (Figure 7)
- increasingly unstable streambanks,
- loss of large woody cover, and
- a simpler and more uniform habitat structure with reduced pool depths, loss of riffles, fewer meanders, and rocky bottoms filled in with sediment^{xix}

When site conditions change to increase the amount of runoff, the velocity of flow can also increase. Impervious surfaces, compacted soils, and reduced vegetation density all can

reduce the roughness of the land surface which accelerates runoff velocity and concentrates flow. These changes increase the energy available for erosion of sediment and transport of nutrients. For instance, the runoff velocity from a parking lot is four times greater than from a meadow during a two-year storm.^{xx}



Water quality

Along with the increased erosive power of stormwater runoff that accompanies increased impervious surfaces, come more pollutants that are washed from developed waterfront properties and surrounding areas into the adjacent lakes and streams. Pollutants frequently found in stormwater runoff include: sediment, nutrients, metals, hydrocarbons, bacteria and pathogens, organic carbon, pesticides and deicers.^{xxi} This summary will focus on sediment, nutrients and temperature. Table 3 provides further information about the impacts of various water pollutants.

Table 3. Surface water pollutants

Pollutant	Source in Nature	Role in Natural Ecosystem	Source in Developed Areas	Role of Excess Pollutant
Sediment	Banks of meandering channels and shorelines	Maintain stream profile and energy gradient; store nutrients	Construction sites; eroding banks	Abrade fish gills; carry excess nutrients and chemicals; block sunlight; cover gravel (spawning) & bottom habitats
Organic Compounds	Decomposing organic matter	Store nutrients	Car oil; herbicides; pesticides; fertilizers	Deprive water of oxygen by decomposition
Nutrients	Native soils & decomposing organic matter transported by natural runoff rates	Support ecosystems Sustain plant base of food chain	Organic compounds; organic litter; fertilizers; food waste; sewage	Unbalance ecosystems; produce algae blooms & aquatic plant excess; deprive water of oxygen by decomposition
Trace Metals	Mineral weathering	Support ecosystems	Cars; construction materials; coal burning power plants; anthropogenic chemicals	Reduce resistance to disease; reduce reproductive capacity; alter behavior; chronic & acute toxicity depending on concentration
Chloride	Mineral weathering	Support ecosystems	Pavement deicing salts, water softener salt	Sterilize soil and reduce biotic growth
Bacteria	Native animals	Natural decomposition & nutrient cycling	Waste handling areas; domestic & agricultural animals	Cause risk of disease to humans & wildlife
Oil	Decomposing organic matter	Store nutrients	Cars, paving	Deoxygenate water

Modified from Ferguson, B. K. 1998. *Introduction to Stormwater: Concept, Purpose, Design*, New York: John Wiley & Sons, Inc.

Sediment loading increases during construction and when impervious surfaces are increased.

Sediment buries plant and animal habitat critical to healthy streams, lakes and wetlands. Sediment can cover aquatic insects and mussels, warm streams, decrease flow capacity, increase flooding, transport other pollutants that bind to sediment particles, and decrease light penetration to bottom-dwelling plants.^{xxii}

Sediment sources in developed watersheds include stream bank erosion; erosion from exposed soils, such as from construction sites; and sediment washed off impervious areas.^{xxiii} The unit area pollutant load delivered by stormwater runoff to receiving water increases in direct proportion to the coverage of a watershed by impervious surfaces.^{xxiv} Sediment loads from two small construction sites – one residential

and one commercial – found sediment loads were 10 times larger than typical loads from rural and urban land uses in Wisconsin.^{xxv}

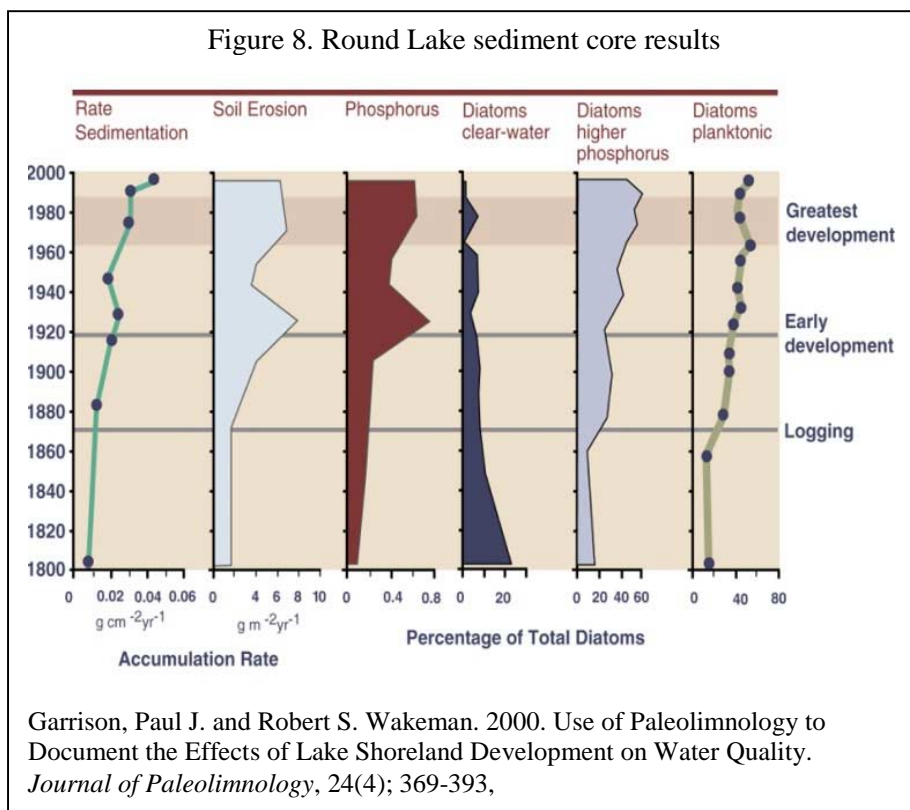
A long-term study of Wisconsin lakes found the greatest sediment and nutrient loading during construction periods.

A study of lakebed sediment cores spanning the last 150 years from four Wisconsin lakes noted that initial development resulted in small but significant impacts on the lake's nutrient status. The construction period, whether during the early development phase or during later home improvement, caused the greatest increase in sediment and nutrient inputs. In the last half of the twentieth century the expansion or replacement of cottages with much larger homes has had the largest impact on all of the lakes. The sediment delivery was higher and the nutrient input was also elevated compared with the initial construction period

(~1920). As cottages were converted to year-round homes or upgraded for seasonal use, more land was disturbed in order to enlarge the dwellings as well as add additional structures such as garages. In many cases, lots were suburbanized which removed much of the native vegetation and replaced it with mowed lawns.^{xxvi} Figure 7 illustrates the results of this study for Round Lake in Chippewa County. Namely, during the 1920s when cottages were built, and during the 1970s and 80s when the cottages were expanded or replaced with larger homes, increases were seen in sedimentation, soil erosion, phosphorus deposition, and diatoms (algae) that survive in higher phosphorus water and float on the surface (planktonic), while algae species that survive in clear water decreased.^{xxvii}

Phosphorus is the key nutrient for most Wisconsin lakes.

In more than 80% of Wisconsin's lakes, phosphorus is the key nutrient affecting the amount of algae and aquatic plant (weed) growth. Phosphorus originates from a variety of sources including: human and animal wastes, soil erosion, detergents, septic systems and runoff from farmland or lawns.^{xxviii} The amount of in-lake phosphorus is the result of phosphorus loading to the lake as well as internal recycling from the sediment. A concentration of total phosphorus below 20 parts per billion (ug/L) for lakes and 30 parts per billion for impoundments should be maintained to prevent nuisance algal blooms.^{xxix} Additional results of high phosphorus levels include excessive aquatic plant growth, decreased oxygen levels and resulting fish kills.



The amount of phosphorus delivered to lakes and stream per acre of land typically increases from forested land to residential development to cropland.

Median concentrations of pollutants in residential runoff are usually higher than in runoff from forest, pasture and open space. Cropland, on the other hand, often produces higher sediment and nutrient loading than residential development.^{xxx} Thus, conversion from intensively managed crops to low density residential development may result in a slightly decreased sediment or nutrient load. On the other hand, land uses with greater than 30% impervious surface will tend to equal or exceed cropland loadings.^{xxxi} Figure 9 shows the amount of phosphorus delivered to lakes and streams from forest, residential and agriculture based on a study of 35 watersheds in southern Wisconsin.^{xxxii}

These results are corroborated by a 1985 Maine study that found a 720% increase in the amount of phosphorus exported to streams when the watershed was developed with sewered lots averaging 1.2 acres in size compared with an undeveloped watershed with similar soils and slopes.^{xxxiii} The developed watershed in this study had 41% forest cover and 15% impervious surface. Additionally, preliminary results from a 2001-2002 USGS study in Forest and Vilas counties comparing waterfront forested and residential lawn sites found the lawn sites contributed seven times more phosphorus and ten times more nitrogen than the forested sites, due to significant increases in runoff volume.^{xxxiv}

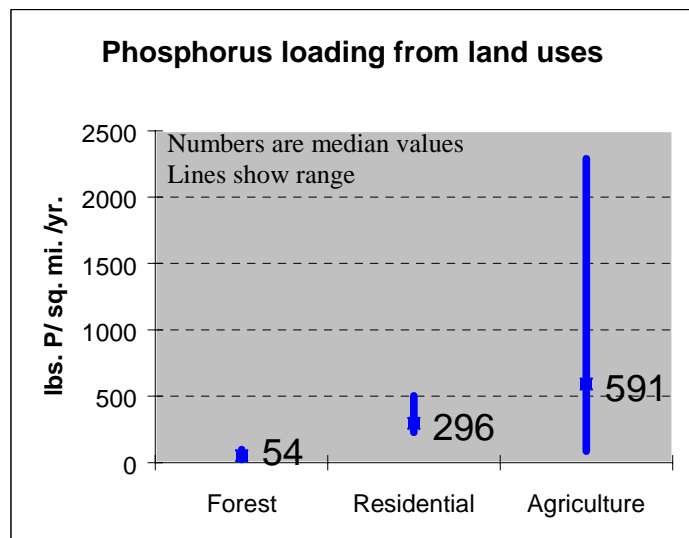
Impervious surfaces increase water temperature.

Impervious surfaces heat the air, water and people around them – an effect obvious to anyone who has walked across a parking lot on a hot summer day. A study in Minnesota found stream temperature increases up to 10 degrees Fahrenheit after summer storm events in an urban area.^{xxxv} Increased water temperatures eliminate trout and other fish that can only survive in cold water. Increased temperature is also important because water does not hold as much oxygen when warmed. Thus, increased temperatures make the aquatic system more susceptible to other stresses such as added nutrients that use up oxygen.

Fish and wildlife habitat

Wildlife are attracted to lakes and streams because the essentials of life for many species occur there, including food, water, shelter, and a place to raise their young. The variety of terrestrial and aquatic plants provide a mosaic of wildlife habitat. The tree canopy provides foraging and nest sites for many species of neotropical migratory birds. The understory is used by nesting birds and also provides cover, foraging sites and travel corridors for mammals such as fox, coyote, mink and fishers. Dead trees or “snags” are often used as dens, nest sites and perching and foraging sites by species such as wood ducks, hooded mergansers, owls, woodpeckers, and belted kingfishers while fallen trees are utilized by species as diverse as fish, amphibians and black bears. Birds such as thrushes and ovenbirds nest amongst the ground cover

Figure 9.



Panuska, John C. and Richard A. Lillie. 1995 Phosphorus Loadings from Wisconsin Watersheds: Recommended Phosphorus Export Coefficients for Agricultural and Forested Watersheds. *Research Management Findings*, No. 38, Bureau of Research, Wisconsin Department of Natural Resources. 8 pp.

on the forest floor, while shoreline grasses provide forage and shelter for small mammals such as shrews, weasels, lemmings, voles and deer mice. Emergent and submerged aquatic vegetation near the shore provides food and shelter for a whole host of critters such as fish, frogs, toads, muskrats, mink, otter, beaver and waterfowl. Therefore, it follows that the more diverse the habitat is along lakes and streams, the more abundant and diverse wildlife will be. The attraction of wildlife to shorelines is evidenced by well-worn game trails that surround most undeveloped shorelines.^{xxxvi}

The quality of fish and wildlife habitat generally decreases as the density of development increases along shorelines. Changes in water quality, bottom sediment, water levels and terrestrial and aquatic vegetation all contribute to this decline.

Aquatic and terrestrial plants are significantly reduced on developed shorelines compared to undeveloped shorelines.

Because aquatic and terrestrial plants serve many functions – from spawning habitat, shelter and foraging opportunities for a variety of fish to nesting material, cover and food for waterfowl and shorebirds - they are crucial to high quality fish and wildlife habitat.^{xxxvii}

Emergent and floating-leaf plants are removed for boat access, docks, and piers, and by motorboat operation while submersed plants are cleared for swimming areas.^{xxxviii}

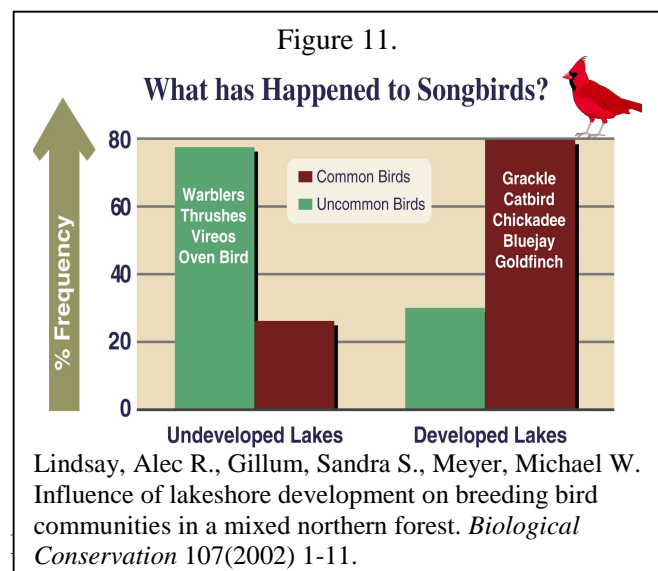
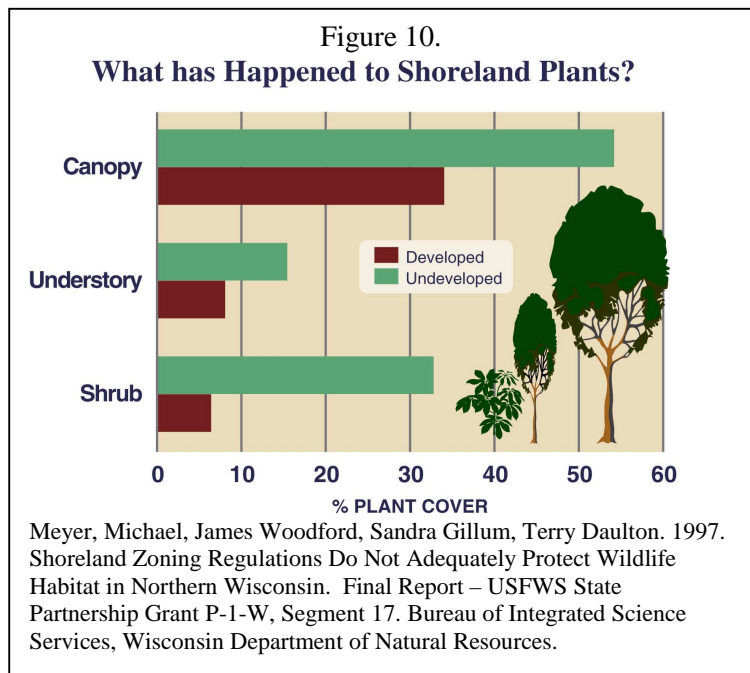
Researchers studying northern Wisconsin lakes found developed shorelines averaging one home per 330 feet of shoreline had 92% less floating-leaf coverage and 83% less emergent coverage than undeveloped shorelines.^{xxxix} In addition, all three stories of terrestrial vegetation (canopy, understory and shrub) were significantly reduced on developed shorelines compared to undeveloped shorelines (Figure 10).^{xl} Trees that have fallen in the water (coarse woody cover) constitute another important component of wildlife habitat –natural fish cribs, basking areas for reptiles and feeding sites. A study of 16 lakes in Northern Wisconsin and Upper Michigan found that cabin occupied sites contained only one-tenth as many downed trees as undeveloped sites.^{xli}

On shore...

Bird species shift and frogs are eliminated on highly developed shorelines.

As nesting cover and foraging areas are eliminated, fragmented or degraded, native wildlife declines in diversity and abundance.^{xlii}

As shown in Figure 11, while a northern Wisconsin study found no decrease in overall bird abundance, there were significant declines on developed shorelines in insect-eating and ground-



nesting birds such as loons and warblers, contrasting with increases of seed-eating birds and deciduous-tree nesting birds such as crows and goldfinches.^{xliii} In short, “city birds” are favored on developed shorelines over other species.

Fewer green frogs were found on lakes in northern Wisconsin when the shorelines were developed (Figure 12). Frogs were eliminated from shorelines with 100-foot lots (52 homes per mile).^{xliv} This is likely due to loss of habitat, habitat fragmentation, and increased susceptibility to predators.

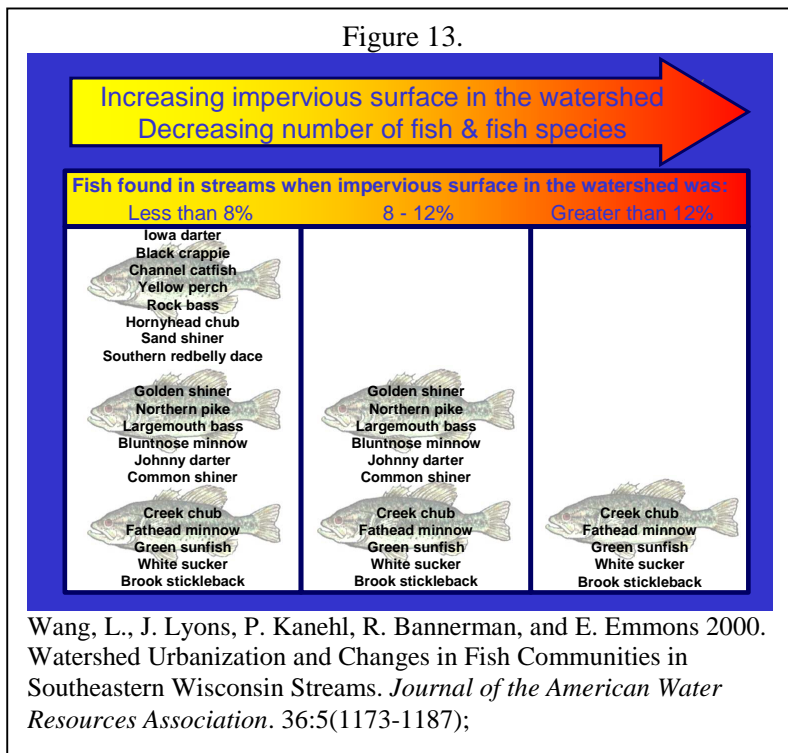
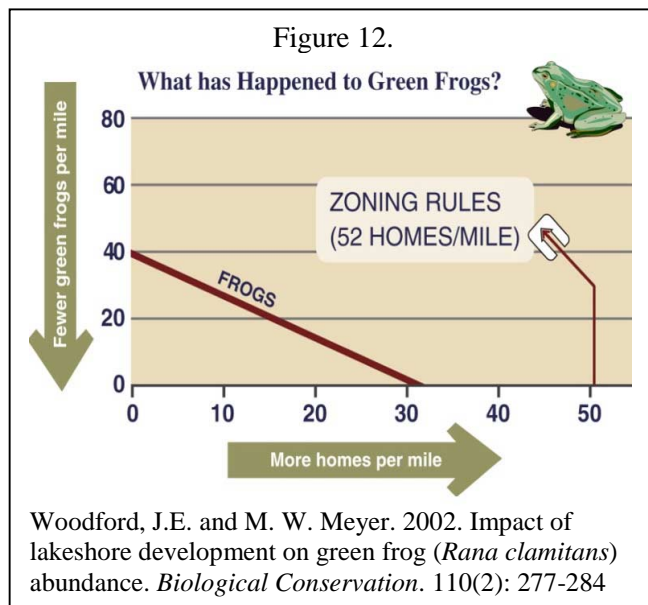
In the water...

Fish and aquatic insects decrease with increasing impervious surfaces.

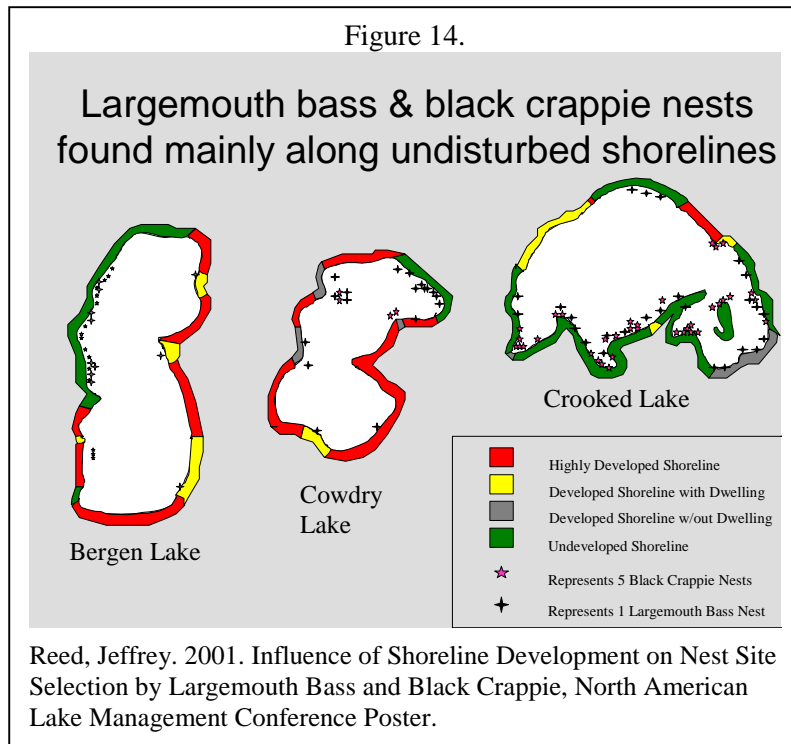
The aquatic insect community is an important component of the food chain in streams^{xlv} and many species find shelter in the large pore spaces among cobbles and boulders. When fine sediments fill these pore spaces, it reduces the quality and quantity of habitat available to aquatic insects.

Aquatic insects are valuable stream quality indicators because they have limited ranges and short life cycles, and, unlike fish, they are abundant in most small streams. Over 20 years ago researchers found that aquatic insect diversity drops sharply in streams where watershed impervious surface exceeded 10 to 15%.^{xlvi}

Besides the detrimental impacts on aquatic insects, fine sediments also affect fish spawning, egg incubation and fry-rearing. Figure 13 illustrates results from a study of 47 warm water streams in southeast Wisconsin that found that fish and insect populations decline dramatically when impervious surfaces exceed about 8-10% of the watershed. Streams with more than 12% imperviousness have consistently poor fish communities.^{xlvii}



Examination of black crappie and largemouth bass nests on three Minnesota lakes found only 74 of 852 crappie nests near shorelines that had any type of dwelling on it (Figure 14). The largemouth bass were slightly more tolerant of shoreline development, but they still nested along undeveloped areas far more often that could be explained by chance. Both black crappie and largemouth bass preferred undisturbed shoreline for nest construction, indicating that as shoreline continues to be developed, both species may be crowded into fragmented habitat.^{xlviii}



Natural shoreline beauty

The aesthetics of a shoreline may be an intangible concept, but many people often recognize when it has been degraded or lost. In a Minnesota survey, waterfront property owners and lake users cited cabin and home development over 85% of the time as the cause when they perceived a decline in the scenic quality on the lake they used the most. Other activities at the top list that resulted in a decline in scenic quality included installation of docks and boat lifts, and removal of trees and shrubs in the shoreland area.⁵

These man-made elements are often seen as visual intrusions in a natural setting – they “grab” our attention and interrupt or upset the natural character of a setting. In general, landscape aesthetic assessment literature has found that more natural scenes, those in which human presence or activities are relatively less visually apparent, are consistently preferred over scenes where human development is more obvious.⁶ To reduce the obvious nature of man-made elements, landowners may keep clearings and land disturbances to a minimum and retain vegetation to screen structures from view.⁷

Mitigation

Can the negative effects of shoreland development density and impervious surfaces on water quality, wildlife and natural shoreline beauty be effectively mitigated? Partially. One difficulty is that watershed practices are seldom installed consistently across an entire subwatershed and where they are installed they may be inadequately constructed or maintained.^{xlix} The remainder of this section will summarize research analyzing the following mitigation techniques:

- Low impact design
- Avoiding or reducing soil compaction
- Stormwater ponds
- Shoreline buffers
- Seeding and mulching construction sites

- Reduced application of fertilizers

Low impact design increases infiltration, thereby decreasing runoff

Traditional storm water management seeks to remove runoff as quickly as possible, gathering excess runoff in detention basins for peak reductions where necessary. In contrast, more recently developed low impact design (also known as open space subdivisions, conservation subdivisions or cluster designs) increases contiguous open spaces, reduces impervious surfaces, minimizes land disturbing activities such as road and utility installation and promotes infiltration by directing runoff from impervious areas to vegetated areas. This approach has many advantages including:

- Reducing the amount of surface runoff
- Increasing the recharge of local groundwater aquifers and streams
- Reducing erosion and stream widening
- Improving stream quality
- Avoiding additional expense and maintenance associated with traditional engineered storm water infrastructure.¹

Low impact design can do much more to reduce runoff and nutrient loads than best management practices (BMPs; in this case stormwater sewers and a sediment pond), as shown in Figure 4. Utilizing BMPs reduced nutrient loading by less than 5% in this study, whereas switching from a conventional subdivision design to an open space subdivision decreased nutrient loading by 40-50% by locating impervious surfaces farther from waterways and minimizing the amount of impervious surfaces.^{li}

In the open space subdivision significant cost savings were achieved by reducing impervious surfaces by 20% by:

- reducing road widths,
- reducing driveway lengths & widths, and
- using a road loop rather than a cul-de-sac.

Table 4. Nutrient loading from conventional and open space subdivisions

	Nutrient Loads		
	Conventional Subdivision	Conventional Subdivision + BMPs	Open Space Subdivision
Phosphorus (lbs./yr.)	46	44	23
Nitrogen (lbs./yr.)	274	264	156

Center for Watershed Protection. Nutrient Loading from Conventional and Innovative Site Development, July 1998. pp. 26-29.

A recent modeling study found that for rainfall events less than one inch, low impact design is able to fully compensate for increased runoff from development on high infiltration capacity soils and to significantly reduce runoff for the lowest infiltration capacity soils, compared with traditional stormwater management.^{lii} This study also suggests that impacts of impervious surfaces can be minimized by locating them in areas with less pervious soils.^{liii} As shown in Table 5 below, infiltration is the most effective stormwater treatment practice for reduction of total suspended solids and phosphorus.^{liv}

Minimizing land disturbance during construction reduces erosion and soil compaction.

As shown in Figure 15, this approach protects water quality by reducing the amount of sediment and phosphorus delivered to a lake by 18-fold.^{lv} Fencing during construction to exclude construction activity from some areas of the site is an effective proactive measure for avoiding soil compaction.^{lvi}

Seeding and mulching construction sites reduces sediment loads

The amount of solids carried from a residential construction site can be five times greater than a developed site due to removal of vegetation and soil compaction from heavy equipment that leads to more runoff. Seeding and mulching construction sites dramatically reduced sediment loads.^{lvii}

Soil compaction can be reduced.

The most effective means of reducing soil compaction after construction are:

- amending the soil with compost,
- time (on the order of decades), and
- reforestation.^{lviii}

Engineered stormwater treatment practices vary in effectiveness.

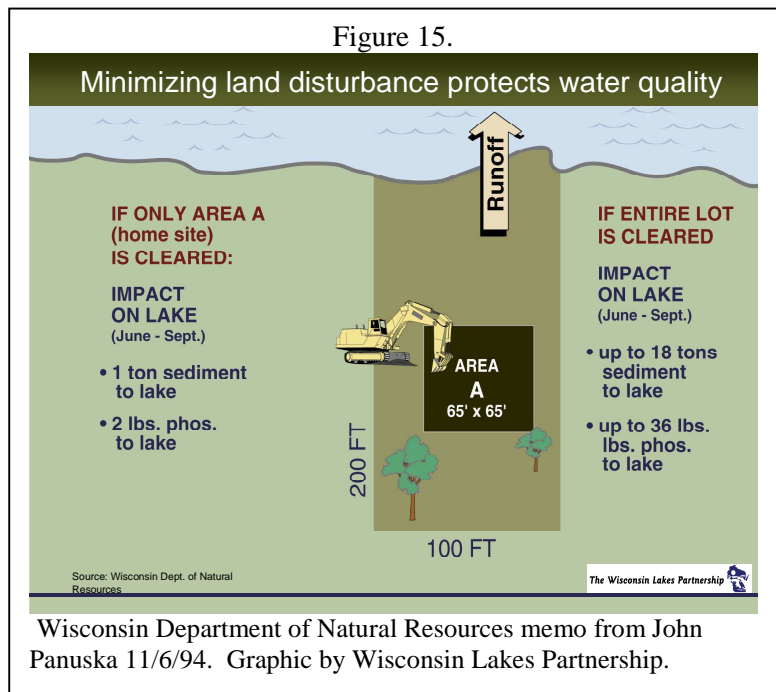
Stormwater ponds are commonly designed with the goal of maximizing pollutant removal, which may lead to different designs than if the goal was to protect stream habitat, prevent downstream erosion or promote aquatic diversity. The degree of pollutant removal by ponds and other stormwater treatment practices is reported in Table 5.

Table 5. Average percent removal rate of pollutants by stormwater treatment practices

Practice	Total suspended solids	Total phosphorus	Nitrogen	Oil/Grease	Bacteria
Infiltration	95%	80%	6%	NR	NR
Dry ponds	47%	19%	9%	3%	44%
Wet ponds	80%	51%	43%	78%	70%
Wetlands	76%	49%	36%	85%	78%
Water quality swales	81%	34%	9%	62%	increase
Ditches	31%	increase	9%	NR	0%

NR = Not Reported

Winer, R. 2000. *National Pollutant Removal Performance Database for Stormwater Treatment Practices*, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.



Three studies found no detectable difference in aquatic insect diversity in streams with or without large stormwater ponds. Four other studies detected a small but positive effect of stormwater ponds relative to aquatic insect diversity. The positive effect of detention was typically seen only in the range of 5-20% impervious surface and was generally undetected beyond about 30% impervious cover. Although each author was hesitant about interpreting results, all generally agreed that perhaps as much as 5% impervious surface could be added to a watershed while maintaining aquatic insect diversity, given effective stormwater treatment.^{lix}

Shoreline buffers have a positive effect on fish and insect diversity.

Five studies all detected a small to moderate positive effect when forested stream buffers were present (frequently defined as at least two-thirds of the stream network with at least 100 feet of stream side forest). If excellent riparian habitats were preserved, they generally reported that fish diversity could be maintained up to 15% impervious surface, and good aquatic insect diversity could be maintained with as much as 30% impervious surface.^{lx}

Reducing application of fertilizers decreases the amount of phosphorus delivered to lakes.

Multiple Wisconsin communities have implemented this straightforward mitigation strategy through educational campaigns to minimize fertilizer use or convert to no-phosphorus fertilizer near water. A United States Geological Survey study found that the amount of phosphorus running off regularly fertilized lawns along Walworth County's Lauderdale Lakes was 1.6 times as great as the phosphorus coming off unfertilized sites.^{lxi}

Conclusion

The changes to the landscape from shoreline development increase runoff and decrease water quality, wildlife habitat and natural scenic beauty. Shorelands are especially sensitive to development activities because of their close proximity to surface waters. There is little opportunity to filter or infiltrate pollutants and nutrients from shoreland sources because they have such a short distance to travel to surface waters. Controlling lot size, width and the extent and location of impervious surfaces are important tools to decrease the *cumulative* environmental impact.

Mitigating the adverse effects after shoreland development has occurred can *reduce* the impact of impervious surfaces and compacted soils. However, it's important to realize that mitigation techniques can be expensive and difficult to consistently implement and maintain.

When trees, shrubs and grasses are replaced with impervious surfaces, especially those located close to the water, the following community benefits are threatened:

- Healthy streams with fish spawning areas, adequate flows and stable banks
- Cool, shady water for a diversity of fish
- Food and habitat for songbirds and other animals
- Natural scenery for relaxation and privacy
- Safe and sufficient groundwater for drinking, irrigation and industry
- Stormwater storage capacity to protect homes from flooding^{lxii}

A unique opportunity to preserve these community amenities for future generations is provided in the development density and impervious surface components of shoreland zoning.

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- ⁱ Hunt, Randall J. and Jeffrey J. Steuer, Evaluating the Effects of Urbanization and Land-Use Planning Using Ground-Water and Surface-Water Models. USGS fact sheet FS – 102-01, October 2001
- ⁱⁱ Wis. DNR, The Northern Lakes and Shorelands Study, 1996
- ⁱⁱⁱ Ibid.
- ^{iv} Novitski, R.P. 1982. Hydrology of Wisconsin Wetlands. Wisconsin Geological and Natural History Survey Information Circular 40.
- ^v Hunt, R. 2003. Primer on Water Science. Accepted by *Transactions*, Wisconsin Academy of Science
- ^{vi} Wisconsin State Climatology Office – www.aos.wisc.edu/~sco
- ^{vii} WASAL. 2003. *Waters of Wisconsin: The Future of Our Aquatic Ecosystems and Resources*. Madison, Wisconsin: Wisconsin Academy of Sciences, Arts and Letters.
- ^{viii} Center for Watershed Protection. Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph No. 1, March 2003, p.27.
- ^{ix} Hunt, Randall J. and Jeffrey J. Steuer, Evaluating the Effects of Urbanization and Land-Use Planning Using Ground-Water and Surface-Water Models. USGS fact sheet FS – 102-01, October 2001
- ^x Ibid.
- ^{xi} Ibid.
- ^{xii} Schueler, T. 1987. *Controlling Urban Runoff: A practical Manual for Planning and Designing Urban Best Management Practices*. Metropolitan Washington Council of Governments. Washington, D.C.
- ^{xiii} WASAL. 2003. *Waters of Wisconsin: The Future of Our Aquatic Ecosystems and Resources*. Madison, Wisconsin: Wisconsin Academy of Sciences, Arts and Letters, p.12.
- ^{xiv} Holt, 1965. Geology and Water Resources of Portage County, Wisconsin, U.S.G.S. Water-Supply Paper 1796, p. 17
- ^{xv} Wang, L., J. Lyons, and P. Kanehl 2001. Impacts of Urbanization on Stream Habitat and Fish Across Multiple Spatial Scales. *Environmental Management*. 28(2):255-266.
- ^{xvi} Center for Watershed Protection. Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph No. 1, March 2003, p.7.
- ^{xvii} Ibid. p.25.
- ^{xviii} Ibid. p.39.
- ^{xix} Ibid.
- ^{xx} Ibid. p.29. Based on 3.1 inches of precipitation on B soils.
- ^{xxi} Ibid. p.55.
- ^{xxii} Ibid. p.63.
- ^{xxiii} Ibid. p.64.
- ^{xxiv} Ibid. p.14.
- ^{xxv} Owens, David W. et al. *Soil Erosion from Two Small Construction Sites, Dane County, Wisconsin*. USGS Fact Sheet FS-109-00, August 2000.
- ^{xxvi} Garrison, Paul J. and Robert S. Wakeman. Use of Paleolimnology to Document the Effects of Lake Shoreland Development on Water Quality. *Journal of Paleolimnology*, 24(4); 369-393, 2000
- ^{xxvii} Ibid.
- ^{xxviii} Shaw, Byron et al. *Understanding Lake Data*. UW-Extension publication G3582, p.8.
- ^{xxix} Ibid. p.9.
- ^{xxx} Corsi, Steven R., Graczyk, David J., Owens, David W. and Roger T. Bannerman. 1997. Unit-area Loads of Suspended Sediment, Suspended Solids, and Total Phosphorus from Small Watersheds in Wisconsin. U.S. Geological Survey. Fact Sheet FS-195-97, 4 pp.
- ^{xxxi} Center for Watershed Protection. Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph No. 1, March 2003, p.15.
- ^{xxxii} Panuska, John, Richard Lillie; April 1995. Phosphorus Loadings from Wisconsin Watersheds: Recommended Phosphorus Export Coefficients for Agriculture and Forested Watersheds. *Research Management Findings*, No. 38, Bureau of Research, Wisconsin Department of Natural Resources. 8 pp.
- ^{xxxiii} Dennis, Jeffrey 1985. Phosphorus Export from a Low Density Residential Watershed and an Adjacent Forested Watershed. *Proceedings of the 5th Annual Conference, North American Lake Management Society*, Lake Geneva, Wisconsin. pp. 401-407.
- ^{xxxiv} Greb, Steve and Dave Graczyk, personal communication, 5/2/03.

- ^{xxxv} Galli, J. 1988. A Limnological Study of an Urban Stormwater Management Pond and Stream Ecosystem. M.S. Thesis. George Mason University.
- ^{xxxvi} Meyer, Michael, James Woodford, Sandra Gillum, Terry Daulton. 1997. Shoreland Zoning Regulations Do Not Adequately Protect Wildlife Habitat in Northern Wisconsin. Final Report – USFWS State Partnership Grant P-1-W, Segment 17. Bureau of Integrated Science Services Wisconsin Department of Natural Resources, p.2.
- ^{xxxvii} Cray Borman, Susan. The relationship between shoreline development and changes in aquatic plant communities. UW-Madison draft Ph.D. bibliography, May 2002.
- ^{xxxviii} Radomski, P. and T.J. Goeman. 2001. Consequences of human lakeshore development on emergent and floating-leaf vegetation abundance. *North American Journal of Fisheries Management*, 21:46-61; Engel, S. and J.L. Pederson, Jr. 1998 *The construction, aesthetics and effects of lakeshore development: a literature review*. Wisconsin Department of Natural Resources, Research Report 177, Madison, WI.
- ^{xxxix} Meyer, Michael, James Woodford, Sandra Gillum, Terry Daulton. 1997. Shoreland Zoning Regulations Do Not Adequately Protect Wildlife Habitat in Northern Wisconsin. Final Report – USFWS State Partnership Grant P-1-W, Segment 17. Bureau of Integrated Science Services Wisconsin Department of Natural Resources.
- ^{xl} Ibid.
- ^{xli} Christensen, David L., et al. Impacts of Lakeshore Residential Development on Coarse Woody Debris in North Temperate Lakes. *Ecological Applications*, 6(4), 1996, pp.1143-1149.
- ^{xlii} ³ Bernthal, T. 1997. *Effectiveness of Shoreland Zoning Standards to Meet Statutory Objectives: A Literature Review with Policy Implications*. Dam Safety, Floodplain and Shoreland Section, Bureau of Watershed Management, Wisconsin Department of Natural Resources. Madison, WI.
- ^{xliii} Lindsay, Alec R., Gillum, Sandra S., Meyer, Michael W. Influence of lakeshore development on breeding bird communities in a mixed northern forest. *Biological Conservation* 107(2002) 1-11.
- ^{xliv} Woodford, JE and M. W. Meyer. 2002. Impact of lakeshore development on green frog (*Rana clamitans*) abundance. *Biological Conservation*. 110(2): 277-284; Meyer, Michael, James Woodford, Sandra Gillum, Terry Daulton. 1997. Shoreland Zoning Regulations Do Not Adequately Protect Wildlife Habitat in Northern Wisconsin. Final Report – USFWS State Partnership Grant P-1-W, Segment 17. Bureau of Integrated Science Services Wisconsin Department of Natural Resources.
- ^{xliv} Center for Watershed Protection. Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph No. 1, March 2003, p.93.
- ^{xlvi} Klein, R. 1979. Urbanization and Stream Quality Impairment. *Water Resources Bulletin*. 15(4):948-963.
- ^{xlvi} Wang, L., J. Lyons, P. Kanehl, R. Bannerman, and E. Emmons 2000. Watershed Urbanization and Changes in Fish Communities in Southeastern Wisconsin Streams. *Journal of the American Water Resources Association*. 36:5(1173-1187); Wang, L., J. Lyons, and P. Kanehl 2001. Impacts of Urbanization on Stream Habitat and Fish Across Multiple Spatial Scales. *Environmental Management*. 28(2):255-266.
- ^{xlvi} Reed, Jeffrey. 2001. Influence of Shoreline Development on Nest Site Selection by Largemouth Bass and Black Crappie, North American Lake Management Conference Poster, Madison, Wisconsin.
- ^{xlix} Center for Watershed Protection. Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph No. 1, March 2003, p.11.
- ⁱ Holman-Dodds, Jennifer K., A. Allen Bradley, and Kenneth W. Potter. February 2003. Evaluation of hydrologic benefits of infiltration based urban storm water management. *Journal of the American Water Resources Association*. 39(1): 205-215.
- ^{li} Center for Watershed Protection. Nutrient Loading from Conventional and Innovative Site Development, July 1998. pp. 26-29.
- ^{lii} Holman-Dodds, Jennifer K., A. Allen Bradley, and Kenneth W. Potter. February 2003. Evaluation of hydrologic benefits of infiltration based urban storm water management. *Journal of the American Water Resources Association*. 39(1): 205-215.
- ^{liii} Ibid.
- ^{liv} Winer, R. 2000. *National Pollutant Removal Performance Database for Stormwater Treatment Practices*, 2nd Edition. Center for Watershed protection. Ellicott City, MD.
- ^{lv} Wisconsin Department of Natural Resources memo from John Panuska 11/6/94. Graphic by Wisconsin Lakes Partnership.
- ^{lvi} Can Urban Soil Compaction Be Reversed? *Watershed Protection Techniques*. 1(4): 666-669
- ^{lvii} Owens, David W. et al. *Soil Erosion from Two Small Construction Sites, Dane County, Wisconsin*. USGS Fact Sheet FS-109-00, August 2000.

^{lviii} Can Urban Soil Compaction Be Reversed? *Watershed Protection Techniques*. 1(4): 666-669

^{lix} Center for Watershed Protection. Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph No. 1, March 2003, p.11.

^{lx} Ibid. p.12.

^{lxi} Garn, Herbert S. July 2002. Effects of Lawn Fertilizer on Nutrient Concentration in Runoff from Lakeshore Lawns, Lauderdale Lakes, Wisconsin. USGS Water-Resources Investigations Report 02-4130.

^{lxii} Markham, Lynn. Rain and snow: where do they go...and what do they take with them? 2002. *The Land Use Tracker* (Center for Land Use Education newsletter), Volume 1, Issue 3.